JC02 Rec'd PCT/PTO 25 MAR 2002

SUBSTITUTE FORM PTO-1390 U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (If Known, see 37 CFR 1.5)
12406-022001	10/089017

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE00/003291	21 September 2000	30 September 1999

TITLE OF INVENTION
SURFACE STRUCTURED LIGHT-EMITTING DIODE WITH IMPROVED CURRENT COUPLING

APPLICANT(S) FOR DO/EO/US
Ralph Wirth and Klaus Streubel

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☐ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 16 below concern other documents or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☐ Other items or information:

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Leroy Jenkins — Typed Name of Person Signing

U.S. APPLICATION NO. (IF KNOWN) 10/089017	INTERNATIONAL APPLICATION NO. PCT/DE00/003291	ATTORNEY'S DOCKET NUMBER 12406-022001

17. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)- (5)):

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO..... **$740**

International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)..... **$710**

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)..... **$100**

	CALCULATIONS PTO USE ONLY	
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Surcharge of **$130** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$0.00	

Claims	Number Filed	Number Extra	Rate		
Total Claims	9 - 20 =	0	x **$18**	$0.00	
Independent Claims	1 - 3 =	0	x **$84**	$0.00	
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)			**+ $280**	$0.00	
TOTAL OF ABOVE CALCULATIONS =				$890.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$0.00	
SUBTOTAL =				$890.00	
Processing fee of **$130** for furnishing the English Translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f))				$0.00	
TOTAL NATIONAL FEE =				$890.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$0.00	
TOTAL FEES ENCLOSED =				$890.00	
				Amount to be refunded:	$
				Charged:	$

a. ☒ A check in the amount of $890.00 to cover the above fees is enclosed.
b. ☐ Please charge my Deposit Account No. 06-1050 in the amount of $0.00 to cover the above fees. A duplicate copy of this sheet is enclosed.
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1050. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William E. Booth
FISH & RICHARDSON P.C.
225 Franklin Street
Boston, Massachusetts 02110-2804
(617) 542-5070 *phone*
(617) 542-8906 *facsimile*

SIGNATURE : William E. Booth

NAME

28,933

REGISTRATION NUMBER

10/089017

Attorney's Docket No.: 12406-022001 / 1999P4773USN

JC13 Rec'd PCT/PTO 25 MAR 2002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Ralph Wirth, et al.
Serial No. : Unassigned
Filed : Herewith
Title : SURFACE STRUCTURED LIGHT-EMITTING DIODE WITH IMPROVED CURRENT COUPLING

BOX PCT
Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Prior to examination, please amend the application as follows:

In the claims:

Amend claims 4-9 as follows:

--4. (Amended) The light-emitting diode (100) as described in claim 1, characterized in that

- said second electrical contact layer (5) is realized as continuous.--

--5. (Amended) The light-emitting diode (100) as described in claim 1, characterized in that

- said second electrical contact layer (50) is discontinuous and is interconnected by a layer of transparent, light-conducting material.--

--6. (Amended) The light-emitting diode (100) as described in claim 1, characterized in that

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Leroy Jenkins
Typed or Printed Name of Person Signing Certificate

- said second electrical contact layer (50) is arranged on structured and/or unstructured portions of said current-spreading layer.--

--7. (Amended) The light-emitting diode (100) as described in claim 1,

characterized in that

- the vertical structuring (40) is in the form of preferably regularly arranged n-sided ($n \geq 3$) pyramids, frusta of pyramids, cones or frusta of cones.--

--8. (Amended) A method for fabricating a light-emitting diode (100) as described in claim 1,

characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- vertical structuring (40) to improve the decoupling of light is produced in the surface of said current-spreading layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the structured top surface of said current-spreading layer (30).--

--9. (Amended) The method for fabricating a light-emitting diode (100) as described in claim 1,

characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the top surface of said current-spreading layer (30), and

- vertical structuring (40) to improve the decoupling of light is produced in the top surface of said current-spreading layer (30) outside the areas of said second electrical contact layer.--

REMARKS

All amendments have been made to remove multiple dependency while conserving the claimed subject matter. No new matter has been introduced.

Attached is a marked-up version of the changes being made by the current amendment.

Claims 1-9 are now pending. Applicant submits that all of the claims are now in condition for examination, which action is requested. Please apply any charges or credits to Deposit Account No. 06-1050.

Respectfully submitted,

Date: Mar 25, 2002

William E. Booth
Reg. No. 28,933

Fish & Richardson P.C.
225 Franklin Street
Boston, Massachusetts 02110-2804
Telephone: (617) 542-5070
Facsimile: (617) 542-8906

20409333 doc

Version with markings to show changes made

In the claims:

Claims 4-9 have been amended as follows:

4. (Amended) The light-emitting diode (100) as described in [any of the preceding claims] claim 1,

characterized in that

- said second electrical contact layer (5) is realized as continuous.

5. (Amended) The light-emitting diode (100) as described in [any of the preceding claims] claim 1,

characterized in that

- said second electrical contact layer (50) is discontinuous and is interconnected by a layer of transparent, light-conducting material.

6. (Amended) The light-emitting diode (100) as described in [any of the preceding claims] claim 1,

characterized in that

- said second electrical contact layer (50) is arranged on structured and/or unstructured portions of said current-spreading layer.

7. (Amended) The light-emitting diode (100) as described in [any of the preceding claims] claim 1,

characterized in that

- the vertical structuring (40) is in the form of preferably regularly arranged n-sided ($n \geq 3$) pyramids, frusta of pyramids, cones or frusta of cones.

8. (Amended) A method for fabricating a light-emitting diode (100) as described in [any of the preceding claims] claim 1,

characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- vertical structuring (40) to improve the decoupling of light is produced in the surface of said current-spreading layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the structured top surface of said current-spreading layer (30).

9. (Amended) The method for fabricating a light-emitting diode (100) as described in [any of claims 1 to 8] claim 1,

characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the top surface of said current-spreading layer (30), and
- vertical structuring (40) to improve the decoupling of light is produced in the top surface of said current-spreading layer (30) outside the areas of said second electrical contact layer.

4/prts

Description

Structured-surface light-emitting diode with improved current coupling

The invention concerns a light-emitting diode as set forth in the preamble of Claim 1. In particular, the invention concerns a structured-surface light-emitting diode in which, to improve the uniformity of current supply, an electrical contact layer has a lateral structure by means of which substantially uniform coupling of the electrical current into the light-emitting diode can be achieved.

Light-emitting diodes, such as semiconductor light-emitting diodes (LEDs), are distinguished in particular by the fact that, depending on the system of materials, the internal conversion efficiency of input electrical energy into radiation energy can be very high, i.e., well above 80%. However, the effective decoupling of light from the semiconductor crystal is impaired by the large jump in refractive index between the semiconductor material (typically $n = 3.5$) and the surrounding resin casting material (typically $n = 1.5$). Owing to the resultant small total angle of reflection, of about 26°, at the interface between the semiconductor and the resin casting material, only a fraction of the light generated can be decoupled. With the simple, cubic LED shape typically used in fabrication, a bundle of rays that is not emitted within the roughly 26°-wide decoupling cone remains trapped in the semiconductor crystal, since its angle with respect to the surface normals is not changed even by multiple reflection. As a result, sooner or later the bundle of rays is lost due to absorption, primarily in the area of the contact or the active region or in the substrate. In the case of InGaAlP LEDs, in particular, the absorbing GaAs substrate is a special problem. In conventional LEDs of this kind, the rays emitted from the active region toward the surface of the LED and lying outside the decoupling cone are very likely to be lost in the substrate due to absorption.

The method most commonly used in practice to alleviate this problem is to deposit a thick layer of semiconductor on the top face of the LED. This makes it possible to obtain partial use of the lateral decoupling cones of the emitted luminous radiation.

In US App. 5,008,718 it is proposed, in an AlGaInP LED, to deposit an electrically conductive GaP layer that is transparent to the emitted luminous radiation on the active, light-emitting layers, primarily to bring about lateral spreading of the current injected through an electrical contact. The advantageous side effect of decreasing total internal reflection and the fact that lateral decoupling of the light beam is made possible by the action of the thick GaP layer have been pointed out elsewhere. In addition, it is proposed to remove the GaAs substrate, which is opaque to the emitted light beam, by etching and to replace at least one transparent layer of the substrate with a suitable material, such as GaP.

The use of one or more thick and transparent layers in a light-emitting diode is also proposed in US App. 5,233,204. Various configurations for the arrangement and number of these transparent layers are described. These include disposing below the active, light-generating layer a layer realized in a funnel shape and tapering in the direction of the substrate (Fig. 10).

The earliest computer simulations revealed that surface structuring of the topmost thick, transparent semiconductor layer resulted in improved light decoupling values. In particular, surface structuring comprising preferably regularly arranged n-sided prisms, pyramids or frusta of pyramids, cylinders, cones, frusta of cones and the like led to a marked improvement in the decoupling of light. This is because the rays, which initially travel steeply upward, are reflected at the structured surfaces but travel at a lower angle upon each reflection, so that they ultimately are decoupled laterally from the side walls of the structured regions of the top surface.

Such structured-surface light-emitting diodes were initially fabricated by growing the light-generating semiconductor layers on a semiconductor substrate, followed by the upper thick, transparent semiconductor layer, and then depositing a central electrical contact surface on the top surface of the thick semiconductor layer. The top surface of the thick semiconductor layer was then structured by means of etching technology in the areas outside the central contact surface, after which the back of the substrate was thinned and provided with a back contact. This approach proved to be disadvantageous, however, since the thick semiconductor layer, the so-called window, is fragmented by the structuring, causing the current spreading to deteriorate. Thus, there is no adequate distribution of electrical current in the regions outside the central contact surface, and the improvement in light decoupling brought about by the structuring is therefore offset by the deficient current spread and the increase in overall luminous flux does not turn out as desired.

It is, accordingly, an object of the present invention to provide a light-emitting diode with high effective decoupling of light. In particular, it is an object of the present invention to simultaneously ensure, in a light-emitting diode, good spatial distribution of the initiated electrical current and good decoupling of the optical light beam.

This object is accomplished by means of the characterizing features of Claim 1.

As described therein, the present invention describes a light-emitting diode with a semiconductor layer structure including a substrate and at least one light-generating layer formed on the substrate and one transparent current-spreading layer deposited on the light-generating layer, a first electrical contact layer on the back of the substrate, and a second electrical contact layer disposed on the current-spreading layer, the top surface of the current-spreading layer having vertical structuring to improve the decoupling of light, and the second electrical contact layer having a lateral structure by

means of which substantially uniform coupling of the electrical current into the current-spreading layer can be achieved. The current-spreading layer is preferably relatively thick, particularly within a range of between 5 and 80 ìm.

The invention is therefore based on a combination of surface structuring of the semiconductor, which contributes to the decoupling of light, and an improved current-spreading layer, said function being performed by a second electrical contact layer shaped into, in the broadest sense, a metal contact grid. The term "grid" is to be understood here and in the following not only as a strictly periodic, closed grid, but also as individual contact fingers or another guide composed of metal webs and suitable for establishing contact. Such a grid overcomes the problems of current spreading in structured light-emitting diodes and allows the improved decoupling of light to exert its full effects.

The vertical structuring of the top surface of the current-spreading layer can take any conceivable form. Feasible structures are, for example, n-sided prisms, pyramids or frusta of pyramids, cylinders, cones, frusta of cones and the like.

In particular, the second electrical contact layer can comprise a central, in particular circular contact surface and, arranged about said central contact surface, a contact structure that is rotationally symmetrical with respect to the center point of the central contact surface and is composed of relatively narrow contact webs and/or contact points. The rotational symmetry of the contact structure can be a symmetry represented by a whole number and can, in particular, match the rotational symmetry of the light-emitting diode. The usual case is a rectangular or square light-emitting diode, with the contact structure exhibiting fourfold symmetry.

The second electrical contact layer can be realized as either continuous or discontinuous; in the latter case, the discontinuous portions are interconnected by a layer of transparent, conductive material, for

example indium-tin oxide (ITO).

The second electrical contact layer can be arranged on both structured and unstructured portions of the surface of the current-spreading layer.

The invention is described in more detail hereinbelow with reference to exemplary embodiments associated with the drawings, wherein:

Fig. 1 is a schematic, simplified cross-sectional representation of a light-emitting diode with its surface structured according to the invention, arranged in a reflector;

Fig. 2 is a first exemplary embodiment of the second electrical contact layer in a plan view on the structured light exit surface of the light-emitting diode;

Fig. 3 is a second exemplary embodiment for a second electrical contact layer in a plan view on the structured light exit surface;

Fig. 4 is a third exemplary embodiment of a second electrical contact layer.

Figure 1 shows an LED chip 100, as arranged in a reflector 200 of circular or parabolic cross section, so that the light rays emitted by the chip both are radiated on a direct path and are collected by the reflector 200 and emitted in substantially the same direction. The LED chip 100 is generally embedded in a resin casting material, so that an interface between the semiconductor material and the resin casting material exists in particular on the surface of the chip through which the light exits. A relatively large jump in refractive index is present at this interface, so that total reflection occurs even at relatively low angles of incidence to the normal. Insofar as possible, these totally reflected rays are to be decoupled through the side walls of the LED chip 100 and collected by the reflector 200, instead

of being absorbed in the substrate of the LED chip 100.

A light-emitting diode according to the invention has a semiconductor layer structure comprising a light-absorbing or transparent substrate 10 and at least one light-generating layer 20 formed on the substrate 10. The light-generating layer 20 is formed by a pn junction. If desired, a single or multiple quantum trough structure can be provided as the light-generating layer 20. Grown epitaxially on top of the light-generating layer 20 is a relatively thick, transparent semiconductor layer, the so-called current-spreading layer 30. A first electrical contact layer is deposited on the back of the substrate, covering its entire area, while a second electrical contact layer 50 is deposited on a portion of the current-spreading layer 30. The top surface of current-spreading layer 30 has structuring 40 designed to improve the decoupling of light. In the cross-sectional view of Fig. 1, this structuring 40 is depicted as a plurality of pyramids. These pyramids can have $n \geq 3$ sides, a cone being formed by the pyramids in the limiting case $n = \infty$. The apex can also be cut from the resulting structure, resulting in a frustum of a pyramid or cone. On the surface of the current-spreading layer 30 provided with the structuring 40, a second electrical contact layer 50 is deposited in such a way as to achieve the most uniform possible current coupling. To this end, the second electrical contact layer 50 is deposited with a grid-shaped structure. Exemplary embodiments of the shape of the second electrical contact layer are illustrated in Figs. 2 to 4.

Shown in each of Figs. 2 to 4 is a square-shaped light-emitting diode in a plan view on its light exit side, i.e., on the surface of the current-spreading layer 30 provided with the second electrical contact layer 50. In the exemplary embodiment of Fig. 2, the structuring 40 comprises a plurality of four-sided pyramids or frusta of pyramids arranged in a matrix shape. The second electrical contact

layer 50 can generally be deposited on the unstructured areas of the surface of the current-spreading layer 30, i.e., at the bases of the pyramids. Alternatively, however, it can be deposited directly on the structuring 40. The second electrical contact layer 50 is preferably composed of a bonding alloy, such as Au:Zn or Au:Ge or the like. The exemplary embodiments of Figs. 2 to 4 show feasible shapes for the structure of the second electrical contact layer 50, which are composed of a central, in particular circular or square contact surface 51, and, arranged about said central contact surface 51, a grid structure that is rotationally symmetrical with respect to the center point of central contact surface 51 and is composed of relatively narrow contact webs 52, 53 and/or contact points 54. To obtain the most uniform possible coupling of electrical current, the grid structure of the second electrical contact layer 50 has exactly the same rotational symmetry as the light-emitting diode itself. Consequently, if the light-emitting diode is square-shaped as in the exemplary embodiments, thus having fourfold symmetry, then the grid structure of the second electrical contact layer 50 is also configured with fourfold rotational symmetry about the center point of central contact surface 51.

The design of the contact layer 50 depicted in Fig. 2 has proven especially advantageous. In this exemplary embodiment, contact layer 50 has an outer and an inner circumferential contact web 52. The outer circumferential contact web 52 extends along the edge of substrate 10. The inner circumferential contact web 52 is arranged between the central contact surface 51 and the outer circumferential contact web 52. The outer circumferential contact web 52 and the inner circumferential contact web 52 are connected to each other and to central contact surface 51 via radially extending contact webs 53. Such a structure has proven especially advantageous for uniform current distribution in LED chips 100 of square cross section, because this design for the electrical contact layer 50 combines geometrical simplicity with uniform current distribution.

It is particularly advantageous in this case if the inner circumferential contact web 52 is disposed centrally between the outer circumferential contact web 52 and central contact surface 51, and if the radial contact webs 53 extend along the medians of the edges of light-generating layer 20.

The grid structure of second electrical contact layer 50 can be realized as a continuous structure, as in the exemplary embodiments of Figs. 2 and 3. However, it can also be provided that the structure not be continuous. Such an exemplary embodiment is depicted in Fig. 4. Here, the grid structure comprises a circular central contact surface 51, surrounded in fourfold symmetry by circular contact points 54 that are not directly connected to central contact surface 51. To establish electrical contact between the unconnected portions of second electrical contact layer 50 in such exemplary embodiments as well, once contact surfaces 51 and 54 have been alloyed in, an additional thin, transparent, electrically conductive layer, for example of indium-tin oxide (ITO), is deposited on the structure. However, the grid structure of the second electrical contact layer 50 can also assume another form, for example a meander structure or the like.

The light-emitting diode according to the invention can be fabricated in various ways. Since the second electrical contact layer 50 theoretically can be deposited on the structuring 40, the simplest fabrication method is first to structure the top surface of the current-spreading layer 30 using the feasibilities described, and then to vapor-deposit the second electrical contact layer 50 through a shadow mask having an aperture area in the shape of the desired structure, or to use a sputter process for this purpose. Alternatively, the second electrical contact layer 50 can also first be deposited to cover the entire area by the aforesaid processes and then structured via a lithography and etching step or by the lift-off technique. In a second fabrication variant, the second electrical contact layer 50, with the desired lateral structure, is deposited on the still-unstructured surface of the current-spreading

layer 30 via one of the aforesaid manufacturing processes and the vertical structuring of the top surface of current-spreading layer 30 is then performed, care being taken to avoid damaging the second electrical contact layer 50.

Claims

1. A light-emitting diode (100), comprising

- a semiconductor layer structure including a substrate (10) and at least one light-generating layer (20) formed on said substrate (10) and one transparent current-spreading layer (30) deposited on said light-generating layer (20),
- a first electrical contact layer on the back of said substrate, and
- a second electrical contact layer (50) disposed on said current-spreading layer (30),

characterized in that

- the top surface of said current-spreading layer (30) has vertical structuring (40) to improve the decoupling of light, and
- said second electrical contact layer (50) has a lateral structure by means of which substantially uniform coupling of the electrical current into said current-spreading layer (30) can be achieved.

2. The light-emitting diode (100) as described in claim 1,

characterized in that

- said second electrical contact layer (50) is a central, in particular circular or square contact surface (51) and, arranged about said central contact surface (51), a contact structure (52; 53; 54) that is rotationally symmetrical with respect to the center point of said central contact surface (51) and is composed of relatively narrow contact webs (52; 53) and/or contact points (54).

3. The light-emitting diode (100) as described in claim 2,

characterized in that

- the rotational symmetry is a symmetry represented by a whole number and in particular matches the rotational symmetry of the light-emitting diode.

4. The light-emitting diode (100) as described in any of the preceding claims,

characterized in that

- said second electrical contact layer (5) is realized as continuous.

5. The light-emitting diode (100) as described in any of the preceding claims,

characterized in that

- said second electrical contact layer (50) is discontinuous and is interconnected by a layer of transparent, light-conducting material.

6. The light-emitting diode (100) as described in any of the preceding claims,

characterized in that

- said second electrical contact layer (50) is arranged on structured and/or unstructured portions of said current-spreading layer.

7. The light-emitting diode (100) as described in any of the preceding claims,

characterized in that

- the vertical structuring (40) is in the form of preferably regularly arranged n-sided ($n \geq 3$) pyramids, frusta of pyramids, cones or frusta of cones.

8. A method for fabricating a light-emitting diode (100) as described in any of the preceding claims, characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- vertical structuring (40) to improve the decoupling of light is produced in the surface of said current-spreading layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the structured top surface of said current-spreading layer (30).

9. The method for fabricating a light-emitting diode (100) as described in any of claims 1 to 8, characterized in that

- a light-generating layer (20) and thereafter a relatively thick and transparent current-spreading layer (30) are deposited on a substrate (10) and the back of said substrate is provided with a first electrical contact layer,
- a second electrical contact layer (50) having the desired lateral structure is deposited on the top surface of said current-spreading layer (30), and
- vertical structuring (40) to improve the decoupling of light is produced in the top surface of said current-spreading layer (30) outside the areas of said second electrical contact layer.

Abstract

Structured-surface light-emitting diode with improved current coupling

In a light-emitting diode (100) having a light-generating layer (20) and a relatively thick, transparent current-spreading layer (30), vertical structuring of the top surface of the current-spreading layer (30) serves to improve the decoupling of light, while at the same time, a second electrical contact layer (50) with a distributed, lateral structure operates to achieve substantially uniform coupling of electrical current into the current-spreading layer (30).

FIG. 2

FIG 1

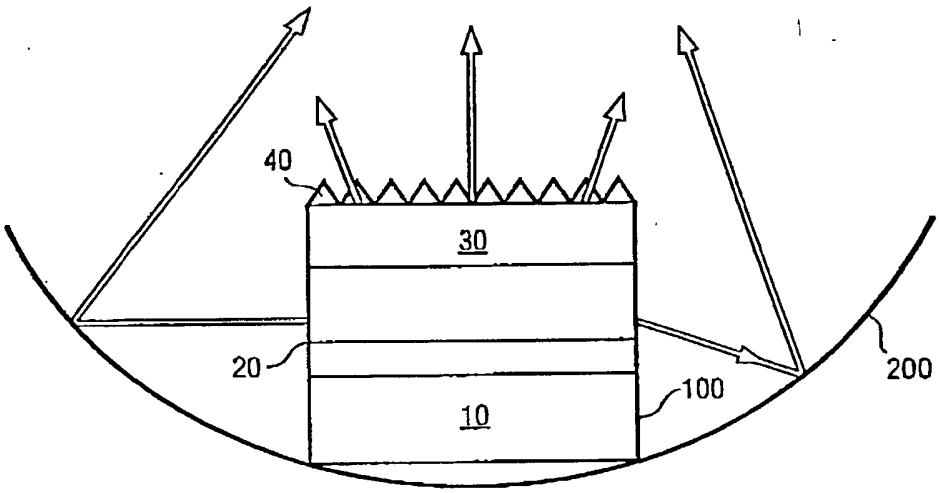


FIG 2

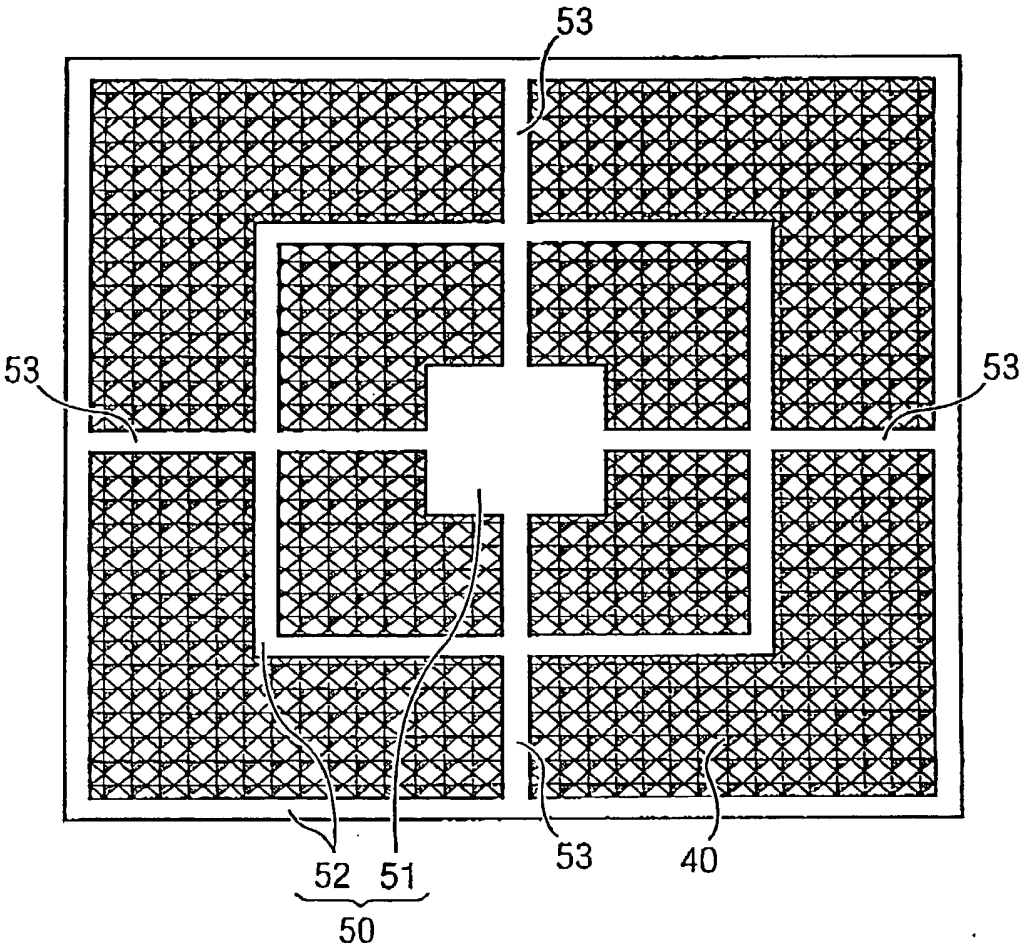


FIG 3

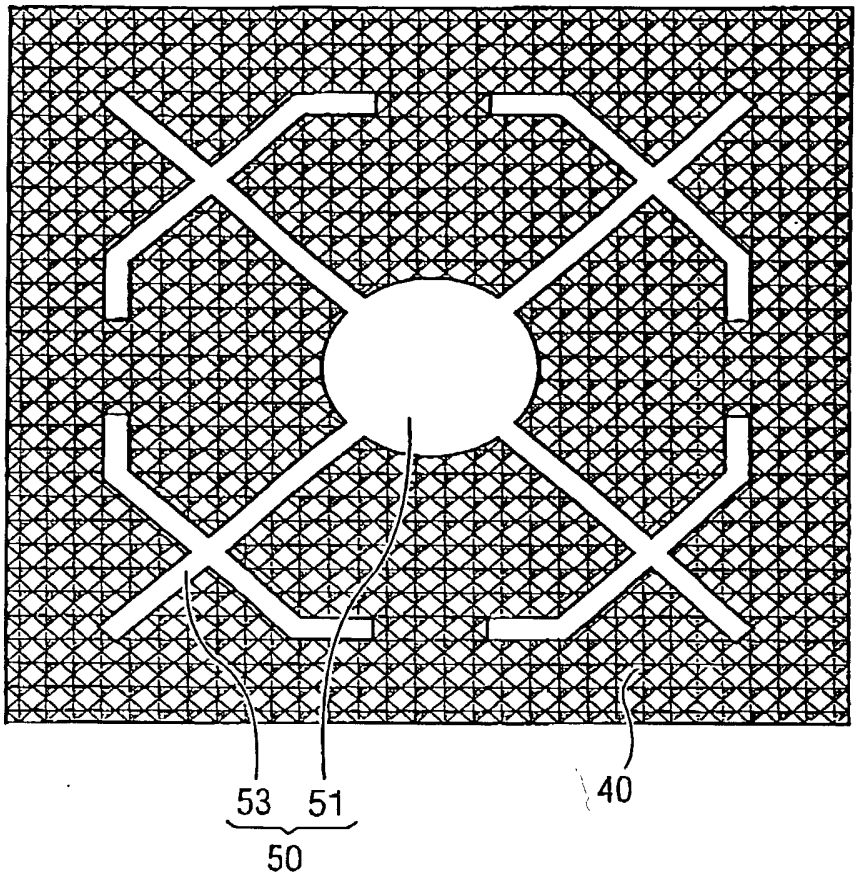
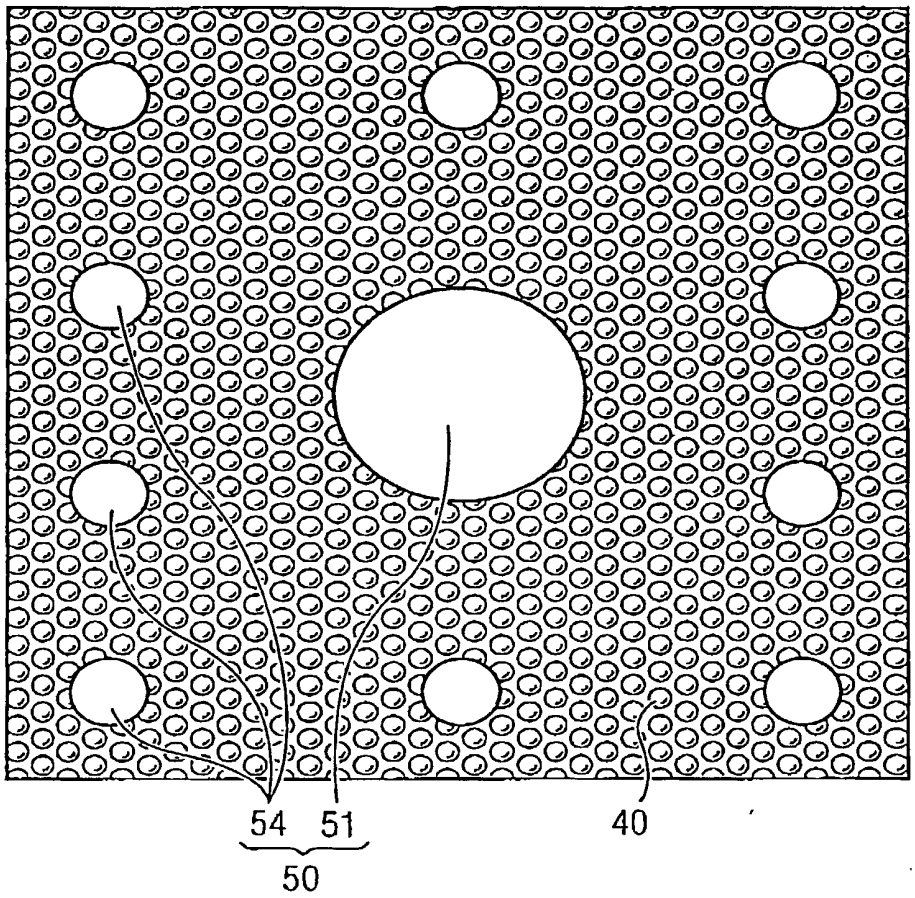


FIG 4



Attorney's Docket No.: 12406-022US1
Client's Ref. No.: 1999P4773USN

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled SURFACE STRUCTURED LIGHT-EMITTING DIODE WITH IMPROVED CURRENT COUPLING, the specification of which:

[ ] is attached hereto.
[X] was filed on March 25, 2002 as Application Serial No. 10/089,017 .
[X] was described and claimed in PCT International Application No. PCT/DE00/003291 filed on September 21, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim the benefit under Title 35, United States Code, §119(e)(1) of any United States provisional application(s) listed below:

U.S. Serial No.	Filing Date	Status

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose all information I know to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

U.S. Serial No.	Filing Date	Status

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

Country	Application No.	Filing Date	Priority Claimed
Germany	199 47 030.8	September 30, 1999	[X] Yes [] No
			[] Yes [] No

Combined Declaration and Power of Attorney

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

William E. Booth, Reg. No., 28,933

Address all telephone calls to WILLIAM E. BOOTH at telephone number (617) 542-5070.

Address all correspondence to WILLIAM E. BOOTH at:

FISH & RICHARDSON P.C.
225 Franklin Street
Boston, Massachusetts 02110-2804

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Full Name of Inventor: RALPH WIRTH

Inventor's Signature: _____ Date: _____
Residence Address: Auguststrasse 13
93049 Regensburg
Germany
Citizenship: Germany
Post Office Address: Same as above

Full Name of Inventor: KLAUS STREUBEL

Inventor's Signature: Klaus Streubel Date: 3.7.02
July 3rd, 2002
Residence Address: Erlenstrasse 7
93164 Laaber DEX
Germany
Citizenship: Germany
Post Office Address: Same as above

Attorney's Docket No.: 12406-022US1
Client's Ref. No.: 1999P4773USN

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100

Full Name of Inventor: RALPH WIRTH

Inventor's Signature: Ralph Wirth Date: 21. June 2002

Residence Address: Auguststrasse 13
93049 Regensburg DEY
Germany

Citizenship: Germany

Post Office Address: Same as above

Full Name of Inventor: KLAUS STREUBEL

Inventor's Signature: _____ Date: _____

Residence Address: Erlenstrasse 7
93164 Laaber
Germany

Citizenship: Germany

Post Office Address: Same as above